



**Field Report
AM IBOC Nighttime Performance**

October 20, 2003

iBiquity Digital Corporation

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1. Performance Testing Overview and Conclusions:

iBiquity, in conjunction with the NAB's Ad Hoc Committee on Nighttime AM IBOC, conducted measurements on the nighttime IBOC digital performance of WOR and WLW. The WLW measurements were made during the summer measurement period, Phase I, and the WOR performance measurements were during Phase II, in the winter. In these tests four routes were driven approximately representing paths to the North, East, South, and West. Each route started near the transmission site and ended beyond the point where the digital signal blended to analog. The tests were generally conducted during times where the skywave interference would be at its peak. During Phase II, both WLW and WOR were configured to transmit IBOC, affording an opportunity to demonstrate WOR's digital performance with both analog and digital interferers. Performance testing was conducted on both WLW and WOR following the identical methodology employed for NRSC sponsored daytime AM tests. Vans equipped with signal recording equipment and HD Radio reference receivers were used to record the extent of digital coverage. Details on the performance test procedures and results are in Appendix A.

These performance tests demonstrate the AM HD Radio™ system will provide a digital upgrade to the primary nighttime analog service area for AM stations. Both WLW and WOR have extensive nighttime groundwave coverage. The performance tests established although digital coverage will not extend to all areas currently able to receive analog signals, the digital signal will cover the primary service areas of these stations. These performance tests also demonstrate that first adjacent digital skywave interference will not materially impact nighttime digital coverage.

2. Summary of WLW's Nighttime Digital Performance:

Nighttime reception of hybrid IBOC was found to approximately replicate WLW's groundwave service area due to the relatively low levels of skywave reception and high levels of co and adjacent channel interference in the nighttime AM band. Figure 1 is a map depicting the WLW market with the predicted 2 and 5 mV/m contours highlighted. The map also shows the routes and the recorded digital performance. Averaged across the four radials, the digital signal was received to the measured 3.7 mV/m, as measured by the spectrum analyzer, which for WLW is well beyond the Cincinnati market. The predicted field intensity at the point of digital to analog blend was higher than that measured by the spectrum analyzer. This differential may very well be explained by varying groundwave propagation conditions and skywave interference.

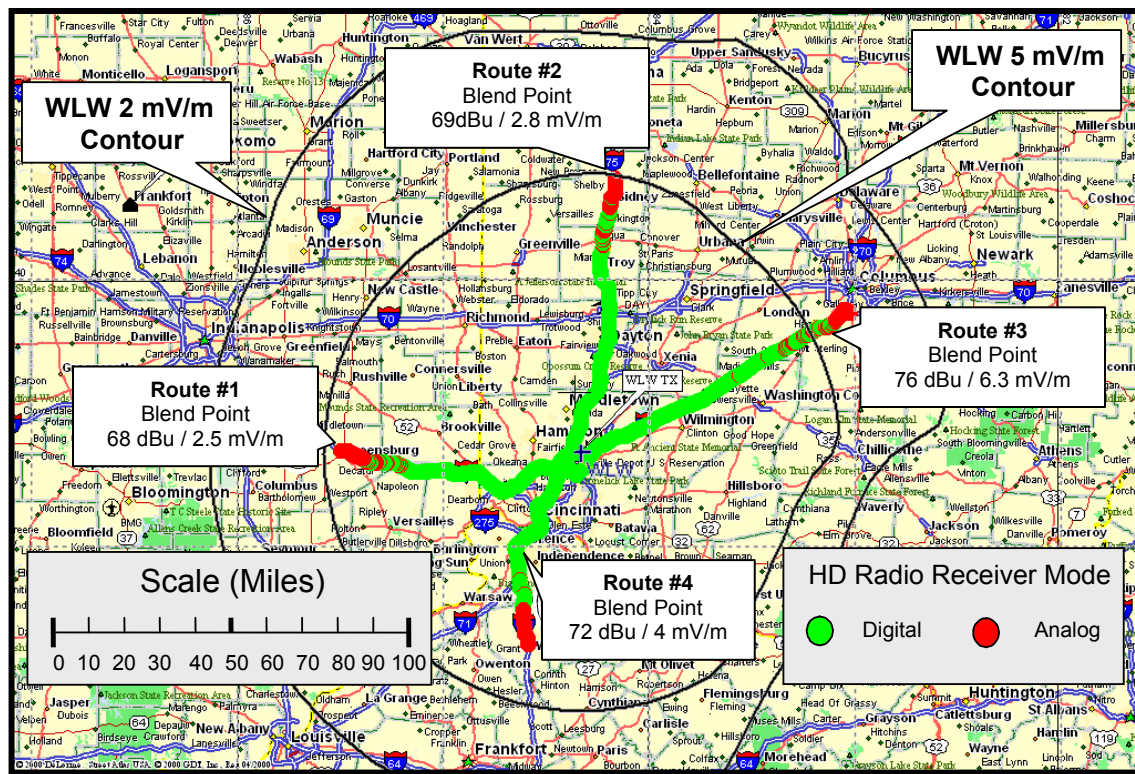


Figure 1: WLW IBOC Digital Nighttime Coverage Performance

3. Summary of WOR's Nighttime Digital Performance:

Figure 2 shows the coverage of WOR's digital signal throughout the New York metropolitan area including Long Island, the Jersey Shore, Western New Jersey and within the directional antenna null to the north. Digital coverage was reliable across the New York metropolitan area, except for regions in Manhattan where severe noise problems prevented the reception of both the digital and analog signals. The point where the digital signal blended to analog, averaged across the four radials, was at the 3.28 mV/m, as measured by the spectrum analyzer. The predicted field intensity at the point of digital to analog blend was higher than that measured by the spectrum analyzer. This differential may very well be explained by varying groundwave propagation conditions and skywave interference.

A second test was conducted to determine whether skywave first adjacent IBOC interference would impact digital coverage for WOR. In this test WLW transmitted with the hybrid IBOC waveform while WOR's groundwave IBOC service area was measured. Figure 3 shows that WLW's digital signal had no noticeable impact on WOR's digital service. The average digital to analog blend point rose only 0.1 mV/m to 3.38 mV/m.

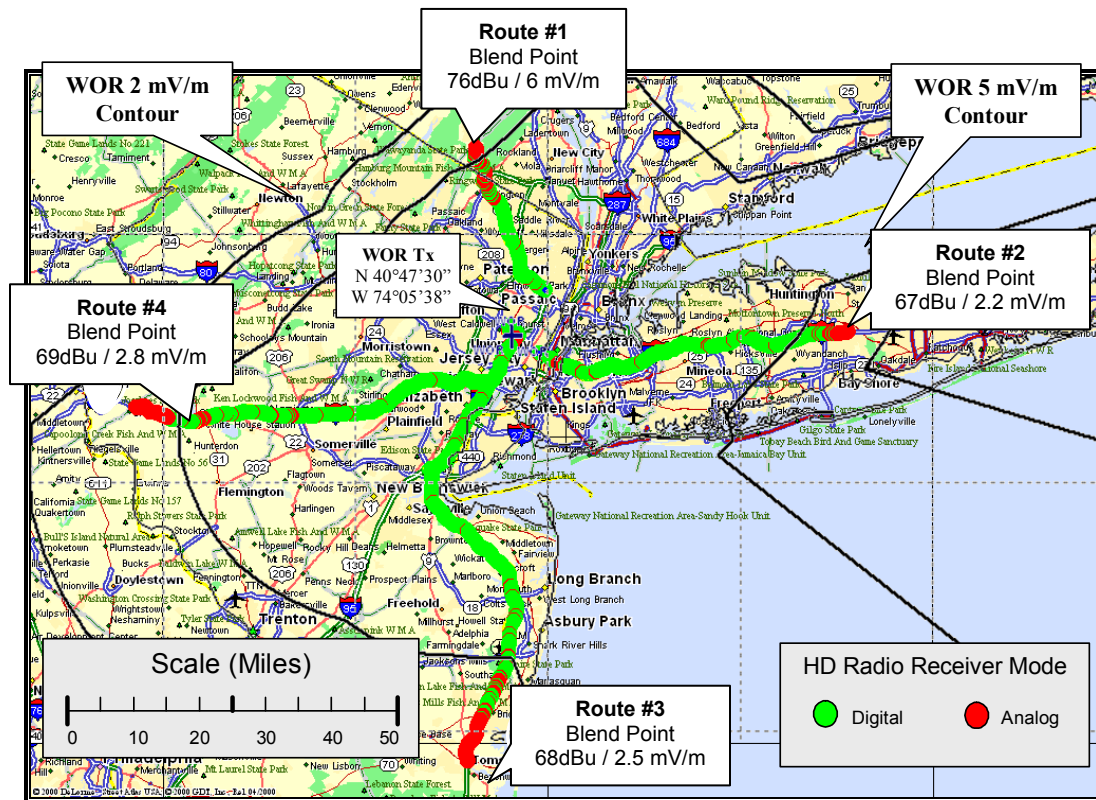


Figure 2: WOR IBOC Digital Nighttime Coverage Performance (w/o WLW hybrid)

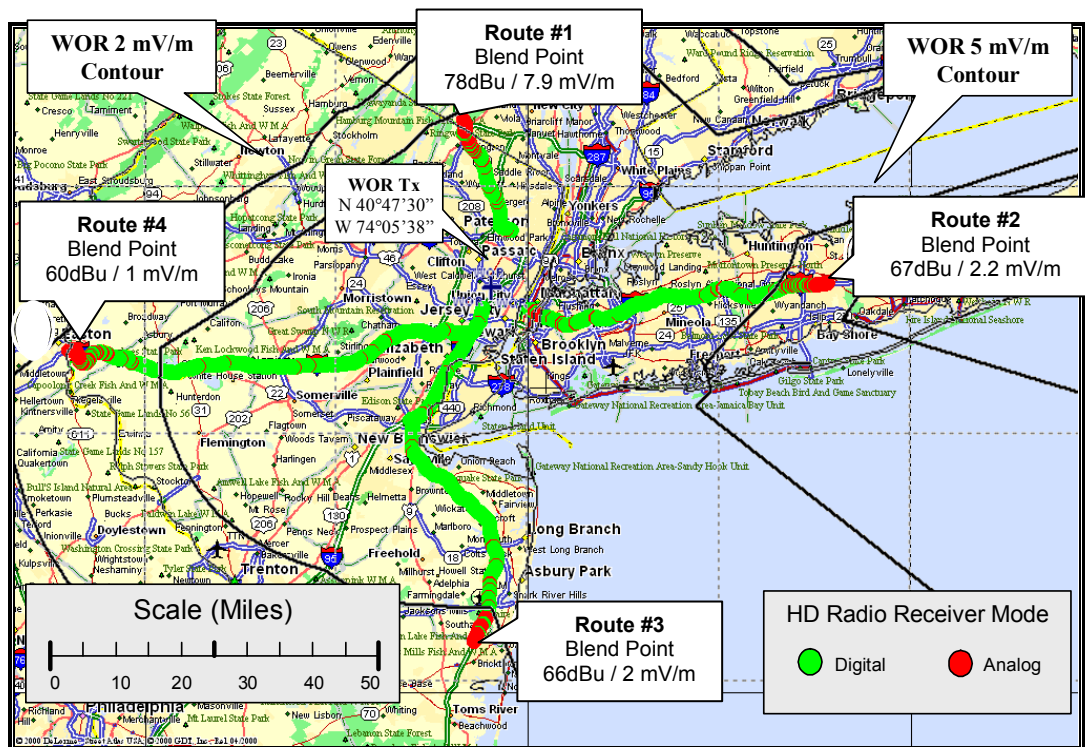


Figure 3: WOR IBOC Digital Nighttime Coverage (with WLW hybrid)



Appendix A

HD Radio Performance: AM Nighttime

WLW, Cincinnati, OH
WOR, New York, NY

August 12 thru 16, 2002
&
December 02 thru 05, 2002

iBiquity Digital Corporation
Columbia, MD—Warren, New Jersey

A1 Performance

This document presents the results of iBiquity Digital Corporation's field test evaluations of the AM HD Radio™ nighttime performance. iBiquity conducted these performance tests in conjunction with the AM HD Radio skywave compatibility test program executed in two phases during the second half of 2002. These tests characterized the HD Radio hybrid transmission mode coverage under the following conditions:

- In the presence of typical nighttime analog interference in the AM band. (Phase I - WLW)
- In the presence of typical nighttime analog interference and first adjacent skywave WLW HD Radio interference in the AM band. (Phase II - WOR)

The performance tests utilized the same first adjacent AM stations iBiquity set up for the compatibility tests: WOR (710 kHz) in New York City and WLW (700 kHz) in Cincinnati, Ohio.

Phase I performance testing was conducted on WLW from August 13 to 15, 2002.

Phase II performance testing was conducted on WOR from December 3 to 5, 2002

iBiquity engineers executed the Phase II performance tests in the New York City area under the observation of the following witness (as approved by an NAB Ad-Hoc committee):

- Thomas Ray – Corporate Director of Engineering, Buckley Broadcasting

A2 Test Description

A2.1 Transmission Site Configuration - WLW

WLW is a Class “A” clear channel station serving the greater Cincinnati, Ohio area with a power output of 50 kW, unlimited, on 700 kHz. The antenna system consists of a single 189.3° series-excited vertical radiator, which produces an essentially circular azimuth pattern as shown in Figure 1. The transmitter site is located at 39°-21’-11” North Latitude / 84°-19’-30” West Longitude as shown in Exhibit M-1, Page A-14.

During Phase I and Phase II testing, iBiquity engineers configured the WLW transmitter site to transmit the hybrid AM HD Radio signal as shown in Figure 2.

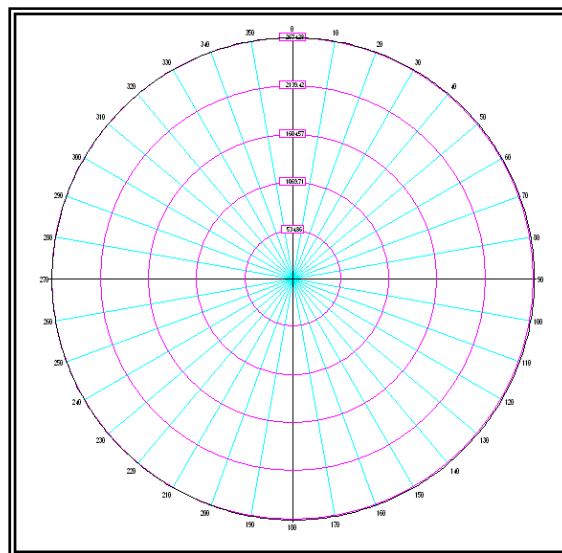
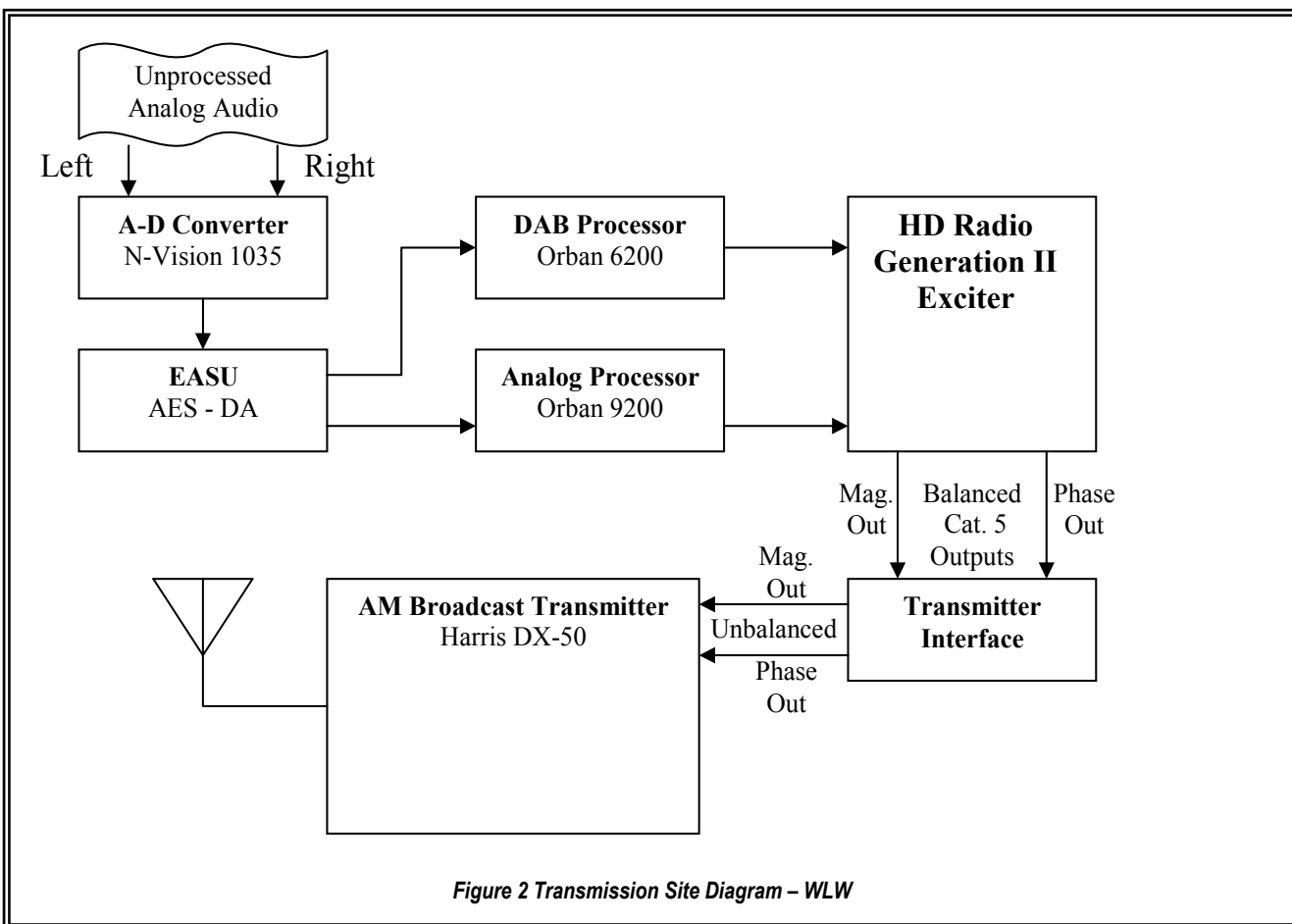


Figure 1



A2.2 Transmission Site Configuration - WOR

WOR is a Class “A” clear channel station serving the greater New York City, New York area with a power output of 50 kW, unlimited, on 710 kHz. The directional antenna system consists of three 177° series-excited vertical radiators, arranged in a “dog-leg” configuration, which produces an oblong azimuth pattern as shown in Figure 3. The transmitter site is located at 40°-47’-30” North Latitude / 74°-05’-38” West Longitude as shown in Exhibit M-2, Page A-15.

During Phase II testing, iBiquity engineers configured the WOR transmitter site to transmit the hybrid AM HD Radio signal as shown in Figure 4.

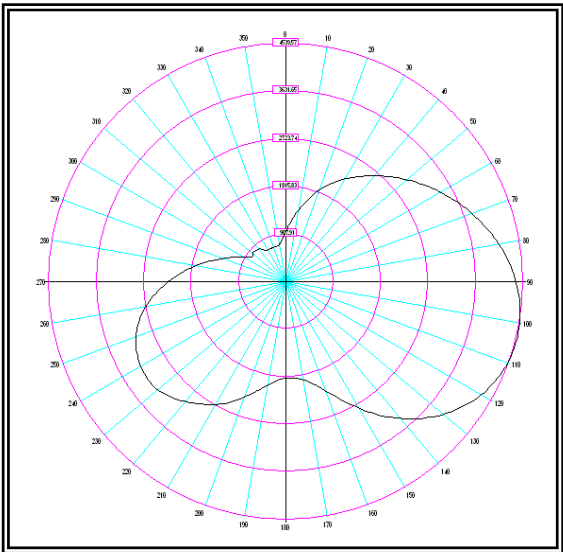


Figure 3

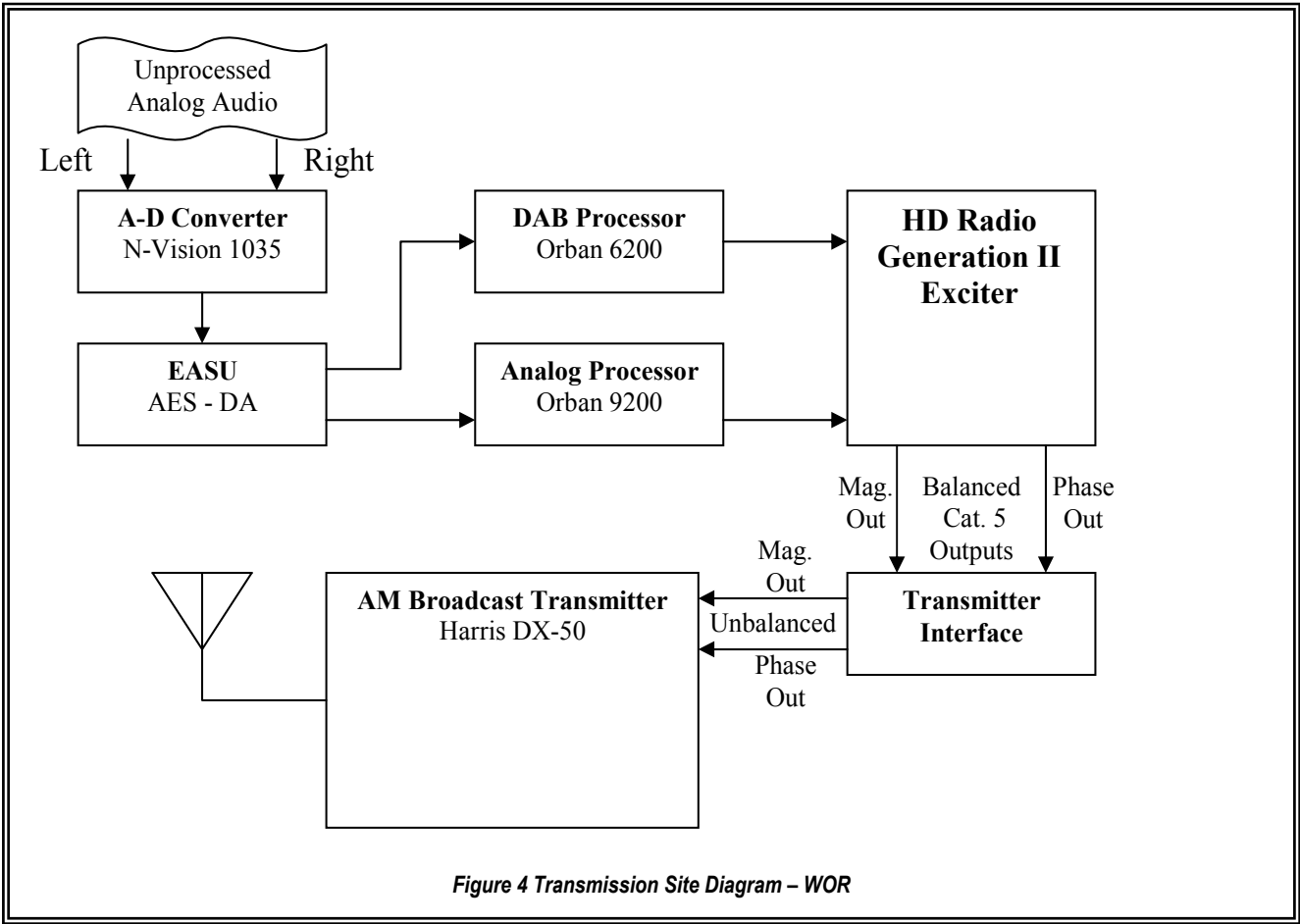


Figure 4 Transmission Site Diagram – WOR

A2.3 HD Radio Waveform & Carrier Levels

Both station's exciter's were configured to transmit the standard HD Radio hybrid waveform, whose spectral representation appears in Figure 5.

A2.4 Drive Test Routes

For each performance test, the drive test routes comprised four radials centered on the desired HD Radio station and each offset from its adjacent radials by about 90 degrees. In all cases, the test vehicle traveled each test radial from the station outward.

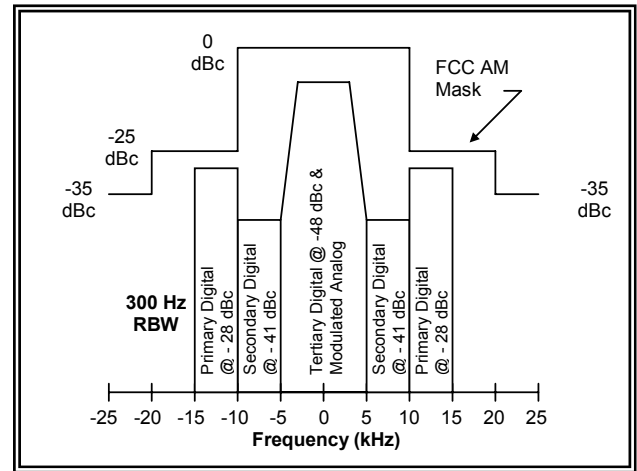


Figure 5

Table A2-1 and Exhibit M-1, (Page A-14) describe the Phase I routes, centered on WLW in Cincinnati.

A2.4.2 Phase II - WOR

Table A2-2 and Exhibit M-2 (Page A-15) detail the Phase II routes extending from WOR, into the New York City Metropolitan area.

Table A2-1 Performance Routes - Phase I - Ohio

Table A2-2 Performance Routes – Phase II – New York

Route	Compass Direction	Route Description POF = Point of Digital Failure	Route	Compass Direction	Route Description POF = Point of Digital Failure
1	Northwest	Start @ WLW Tx Rt. 75 S to Rt. 275 W Rt. 275 W to Rt. 74 W Rt. 74 W to POF	1	North	Start @ Rt. 3 & Rt 17 Rt.17 N to POF
2	North	Start @ WLW Tx Rt. 75 N to POF	2	East	Start @ Rt. 3 & Rt.17 Rt.3 E to Lincoln Tunnel Tunnel to 34 th St. E 34 th St. E to Queens Midtown Tunnel Queens Midtown tunnel to Rt 495 Rt. 495 East (LIE) until POF
3	Northeast	Start @ WLW Tx Rt. 75 S to Rt. 274 W Rt. 274 W to Rt. I-71 W Rt. I-71 W to POF	3	South	Start @ Rt. 3 & Rt.17 Rt.3 East to New Jersey Tpk S NJ Tpk S to Garden State Parkway S GSP South to POF
4	South	Start @ WLW Tx Rt. 75 S to POF	4	West	Start @ Rt. 3 & Rt.17 Rt.3 East to New Jersey Tpk S NJ Tpk S to Rt. 78 W Rt 78 West to POF

A2.5 Test Platforms

Figure 6 depicts the configuration used for both Ohio (Phase I) and New York (Phase II) test vans.

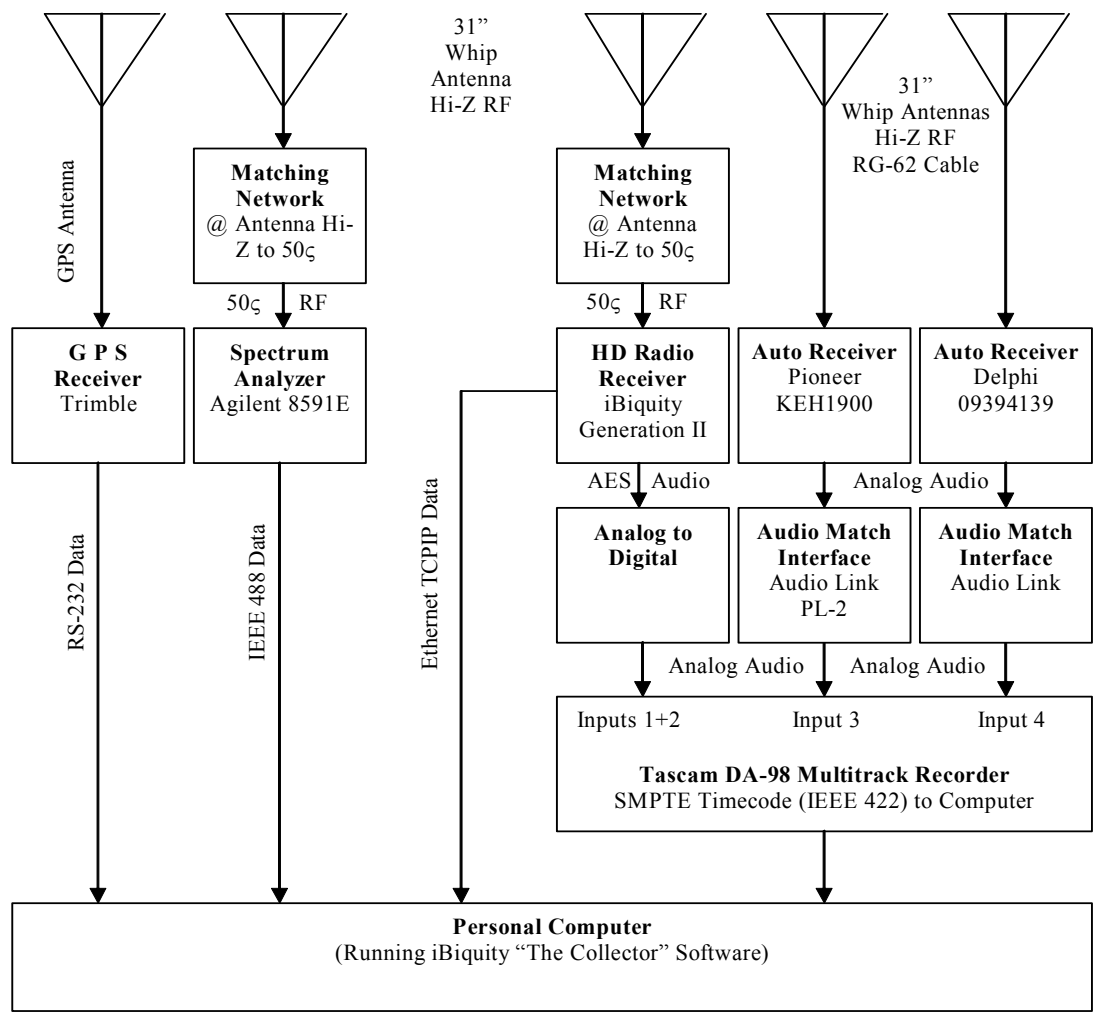


Figure 6

A2.5.1 Receivers and Spectrum Analyzer

Table A2-3 lists the iBiquity Generation II reference receiver and 2 sample consumer receivers used for performance testing. The consumer models were those chosen for the iBiquity NRSC 2001 testing program. Table A2-3 outlines the radio's selectivity and sensitivity profiles, which are typical of those available in the mass marketplace.

Table A2-3 Performance Receivers

Make	Model	Type	Characteristics
iBiquity	Generation II	HD Radio Reference Rx	iBiquity Reference Receiver - 50 Ohm input impedance requires a match for the external ant. (Installed in test vehicle).
Pioneer	KEH1900	Auto	Typical wider IF bandwidth auto radio. Has Hi-Z input impedance tuned to 5 ft. length of RG-62 coax. (Installed in test vehicle). Analog audio recorded for comparison to HD Radio audio.
Delphi	09394139	Auto	Typical narrow IF bandwidth auto radio. Has Hi-Z input impedance tuned to 5 ft. length of RG-62 coax. (Installed in test vehicle). Analog audio recorded for comparison to HD Radio audio.

A dedicated, 31-inch, roof-mounted antenna supplied received signal to each of the radios and the Agilent 8591E spectrum analyzer. Since the spectrum analyzer and the iBiquity HD Radio receiver both had 50 Ohm antenna input impedances, each was provided with a matching network to ensure best signal transfer from its whip antenna in the AM band. The audio outputs of each test radio fed the inputs of a Tascam DA-98 multitrack recorder. The HD Radio receiver, Tascam recorder, spectrum analyzer, and GPS receiver supplied receiver data, timecode, spectral and location data, respectively, to iBiquity's *The Collector* control and data acquisition application running on the van personal computer. During testing, *The Collector* controlled the spectrum analyzer configuration, setting its primary measurement parameters to those listed in Table A2-4.

Table A2-4 Spectrum Analyzer Settings (Performance)

Center Frequency (kHz)	Span (kHz)	RBW (kHz)	VBW (kHz)	Video Averaging	Number of Averages
700 – Phase I	100	3	3	OFF	0
710 – Phase II					

A2.5.2 Data Acquisition Software (*The Collector*)

iBiquity Digital's test vans are all equipped with data acquisition and instrumentation control computers that accumulate data from multiple peripherals using iBiquity's *The Collector* application. Table A2-5 shows the data acquisition system inputs. Figure 7 shows a sample *The Collector* screen.

Table A2-5 Collector Inputs

Device	Data Type	Use
HD Radio Receiver	Audio Mode (TCP-IP over 100baseT)	Receiver audio mode: Digital and Analog
Tascam DA-98 Multi-Track Digital Recorder	SMPTE Timecode (RS-422)	Enables correlation of performance data with recorded audio on tape
GPS Receiver	Latitude, Longitude and Altitude Data (RS-232)	Enables correlation of data with geographic location
Spectrum Analyzer	Spectral Data (IEEE-488)	Enables evaluation of spectral conditions for each sample.
Keyboard	User Input	“F” keys labeled with predefined potential impairments such as “Power Lines”, “Overpass” etc.

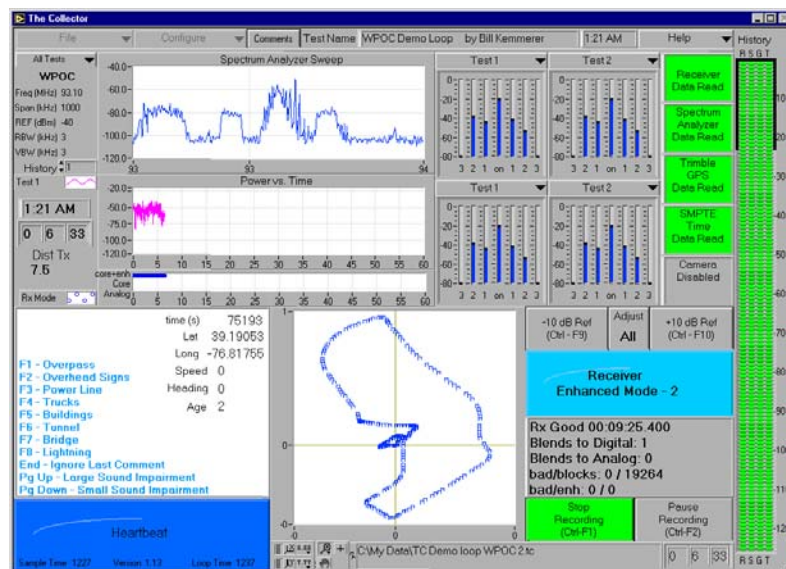


Figure 7 Collector Screen

A2.6 Procedure

In each test phase, a test van configured as shown in Figure 6, collected HD Radio reception data as it traveled the four test radials from the desired HD Radio transmitter. The DA-98 Digital Audio Recorder captured audio from the HD Radio receiver and two representative automotive receivers. As described above, *The Collector* recorded DA-98 SMPTE time code, along with data from the HD Radio receiver, spectrum analyzer and GPS receiver. Table A2-6 lists the routes and test times for Phase I, in which the desired station was WLW, Cincinnati.

Table A2-6 WLW Performance Routes (Phase I)

Route Designation	Compass Direction	Date	Time (EDT)	Route Description POF = Point of Digital Failure
1	Northwest	8/15/02	10:39 PM to 11:37 PM	Start @ WLW Tx Rt. 75 S to Rt. 275 W Rt. 275 W to Rt. 74 W Rt. 74 W to POF
2	North	8/13/02	9:52 PM to 10:50 PM	Start @ WLW Tx Rt. 75 N to POF
3	Northeast	8/14/02	10:28 PM to 12:06 PM	Start @ WLW Tx Rt. 75 S to Rt. 274 W Rt. 274 W to Rt. I-71 W Rt. I-71 W to POF
4	South	8/15/02	1:38 AM to 2:37 AM	Start @ WLW Tx Rt. 75 S to POF

Table A2-7 lists the actual routes and times run for Phase II, which captured the performance of WOR with and without HD Radio interference from WLW.

TableA2- 7 WOR Performance Routes (Phase II)

Route Designation	Compass Direction	Date	Time (EST)	Route Description POF = Point of Digital Failure
1 – With WLW DAB Interference 1 – No WLW DAB Interference	North	12/4/02 12/5/02	4:28 AM to 5:16 AM 3:10 AM to 3:29 AM	Start @ Rt. 3 & Rt 17 Near Transmitter Rt.17 N to POF
2 – With WLW DAB Interference 2 – No WLW DAB Interference	East	12/4/02 12/5/02	2:16 AM to 3:10 AM 12:57 AM to 1:54 AM	Start @ Rt. 3 & Rt.17 Near Transmitter Rt.3 E to Lincoln Tunnel Tunnel to 34 th St. E 34 th St. E to Queens Midtown Tunnel Queens Midtown tunnel to Rt 495 Rt. 495 East (LIE) until POF
3 – With WLW DAB Interference 3 – No WLW DAB Interference	South	12/3/02 12/4/02	11:51 PM to 12:54 AM 10:24 PM to 11:18 PM	Start @ Rt. 3 & Rt.17 Near Transmitter Rt.3 East to New Jersey Tpk S NJ Tpk S to Garden State Parkway S GSP South to POF
4 – With WLW DAB Interference 4 – No WLW DAB Interference	West	12/3/02 12/4/02	9:51 PM to 10:54 PM 8:21 PM to 9:23 PM	Start @ Rt. 3 & Rt.17 Near Transmitter Rt.3 East to New Jersey Tpk S NJ Tpk S to Rt. 78 W Rt 78 West to POF

A3 Data Preparation and Evaluation Methods

iBiquity's *iView* application is a data playback and analysis program that can read and process field test data files created by *The Collector*. *iView* provides two export functions that facilitate graphical analysis of the test data. The first produces a mapping layer file consisting of HD Radio receiver audio mode—analogue (blended) or digital—versus geographical coordinates. Imported into a geographical mapping program such as DeLorme Street Atlas, these overlay data are a multicolored plot of the drive test route. The colors of the route plot correspond to the HD Radio received audio mode. This representation is essentially a digital audio reception coverage map.

A second *iView* export function produces a tab-delimited text file of the complete set of field test data. Each line of this file corresponds to one complete data record, comprising all HD Radio, spectrum analyzer, GPS, SMPTE and timecode data, plus additional calculated parameters for each test sample point. Using a spreadsheet application, it is a straightforward process to create charts of performance versus field conditions for field test route segments. Each of these charts—known as a *radial chart*—contains the following condition and performance information for each sample point along a complete drive test radial:

1. Field Intensity – (instantaneous and averaged)
 - a. 1st Lower Adjacent
 - b. Desired Station
 - c. 1st Upper Adjacent
2. Location (Latitude / Longitude) from GPS
3. Distance from transmitter (miles)
4. HD Radio Receiver Mode
 - a. Digital
 - b. Analog (blended)

The coverage maps and radial charts are the primary data representations used in performance evaluation. The maps and radial charts display coverage versus location along the radial, and the charts further indicate signal strength and the primary interference conditions. In addition to the maps and charts, the desired signal field intensities at the digital/analog audio mode points-of-transition are tabulated.

A4 Results

This section presents a descriptive and tabular analysis of HD Radio nighttime performance based on the points of analog blend. The field intensity at these points was determined by evaluation of the appropriate radial charts and maps as referenced in the Tables A4-1 through A4-3. Examination of the field intensity charts reveals first adjacent field intensities at a level 20 dB below that of the desired carrier for the majority of the run. These levels reflect the amplitude of the station's Primary Digital HD Radio carriers, which run at a level 26 dB below that of the unmodulated analog carrier. As the desired (Co-Channel) to undesired (1st Adjacent) ratio falls below 20 dB near the end of the radial, the analog carrier of the 1st adjacent becomes visible. As the analog carrier of the 1st adjacent is the primary interferer to the desired's HD Radio carriers, the effect of adding digital carriers to the 1st adjacent interferer's signal has a minimal impact on the desired station's HD radio performance.

A4.1 Phase I HD Radio Performance – WLW Nighttime

WLW Nighttime HD Radio performance extended to the following contours for the appropriate blend mode (Table A4-1):

Table A4-1 Blend Points

Radial	Approximate Digital to Analog Blend Point		Exhibit Reference
	dBu	mV/m	
1 - 270°	68	2.5	M1 (Page 14), M7 (Page 17)
2 - 0°	69	2.8	M1 (Page 14), M4 (Page 16)
3 - 45°	76	6.3	M1 (Page 14), M5 (Page 16)
4 - 180°	72	4	M1 (Page 14), M6 (Page 17)
Average	71.25	3.7	

A4.1.1 Radial #1 - 270° Northwest

Blending to analog occurred at 54 miles from the transmitter. The only interferer noted was WOR skywave, which appears to have had minimal impact upon performance until the WLW/WOR DU ratio approached +6 dB.

A4.1.2 Radial #2 - 0° North

Analog blending occurred close to the WLW transmitter due to receiver overload, otherwise, except for a few exceptions, blending to analog did not occur until 58 miles from the transmitter, North of Dayton. The only interferer noted was WOR skywave, which appears to have had minimal impact upon performance until the WLW/WOR DU ratio approached -10 dB.

Note: The sudden drop in field intensity at beginning of run was due to a fuel stop under a metal canopy.

A4.1.3 Radial #3 - 45° Northeast

Blending to analog did not occur until 63 miles from the transmitter. The only interferer noted was WOR skywave, which appears to have had minimal impact upon performance until the WLW/WOR DU ratio approached -10 dB.

A4.1.4 Radial #4 - 180° South

Blending to analog did not occur until 44 miles from the transmitter. It appears that WJIE, Newburg, Ky @ 680 kHz may have impaired digital performance at 44 miles.

A4.1.5 Conclusions

HD Radio nighttime performance on WLW was excellent, fully covering the Cincinnati metropolitan and suburban areas with a robust HD Radio signal. Despite first adjacent skywave and second adjacent groundwave and skywave interference, listeners can expect to receive the WLW nighttime HD Radio digital signal at a minimum of 40 to 60 miles from the transmitter.

A4.2 Phase II HD Radio Performance – WOR Nighttime

WOR Nighttime HD Radio performance extended to the following contours for the appropriate blend mode shown in Table A4-2 with WLW Carriers ON and in Table A4-3 with WLW Carriers OFF:

Table A4-2 New York City WOR HD Radio Performance Data - Phase II - WLW HD Radio Carriers ON

Radial	Approximate Digital to Analog Blend Point		Exhibit Reference
	dBu	mV/m	
1 - 0°	76	6	M2 (Page B-15), M8 (Page B-18)
2 - 90°	67	2.2	M2 (Page B-15), M10 (Page B-19)
3 - 180°	68	2.5	M2 (Page B-15), M12 (Page B-20)
4 - 270°	69	2.8	M2 (Page B-15), M14 (Page B-21)
Average	70	3.38	

Table A4-3 New York City WOR HD Radio Performance Data - Phase II- WLW HD Radio Carriers OFF

Radial	Approximate Digital to Analog Blend Point		Exhibit Reference
	dBu	mV/m	
1 - 0°	78	7.9	M3 (Page B-15), M9 (Page B-18)
2 - 90°	67	2.2	M3 (Page B-15), M11 (Page B-19)
3 - 180°	66	2	M3 (Page B-15), M13 (Page B-20)
4 - 270°	60	1	M3 (Page B-15), M15 (Page B-21)
Average	67.75	3.28	

A4.2.1 Radial #1 - 0° North

The WOR Route 17 North route is almost wholly within the station's directional signal null towards Canada. HD Radio performance in null radials is normally impaired by low signal level, reradiation from grounded conductive structures and dynamic pattern shifts with modulation, referred to as "nulltalk". Additionally, examination of the chart in Exhibit M9 shows a sustained differential in the field intensities of the upper and lower first adjacent plots. These plots effectively represent the level of WOR's HD radio carriers. The differential level is due to a frequency asymmetry in WOR's directional antenna system null location. Digital performance on this radial seems to be influenced more by the above conditions and the current normal ambient skywave propagation conditions than by the presence of WLW HD Radio carriers. In fact, performance appears better with WLW HD Radio carriers on than with them off. As tabulated above, blend to analog occurred at 6 mV/m with WLW HD Radio on and 7.9 mV/m with it off.

A4.2.2 Radial #2 - 90° East

This performance route begins at the transmitter and goes through the Lincoln Tunnel and across Manhattan Island on 34th Street. As the van traveled through New York City, a number of HD Radio receiver mode changes were observed. At these locations, analog reception was poor and in many cases unlistenable due to extensive electromagnetic interference from overhead power lines and other sources. Once through the Queens Midtown Tunnel and onto the Long Island Expressway, reception improved. Blend to Analog occurred at 34 miles from the transmitter and a 2.2 mV/m field intensity with or without WLW HD Radio carriers on. Review of the data shows a higher percentage of the route with the HD Radio receiver in Enhanced mode with WLW HD Radio carriers off. The point of blend to Analog remained the same.

A4.2.3 Radial #3 - 180° South

For this radial, the point of digital failure was approximately 7 miles greater with WLW HD Radio carriers on. The reason for improved performance is unclear, but as the IBOC interferer “ON” mode data were collected later in the evening, skywave reception of the WOR digital carriers may have improved.

A4.2.4 Radial #4 - 270° West

The receiver stayed in the digital mode for a full 20 miles further with WLW HD Radio carriers off than with them on, which could be attributed to differing skywave conditions at the time of testing.

A4.2.5 Conclusions

WOR nighttime HD Radio digital coverage shows no clear impact on WOR’s digital performance due to the WLW DAB carriers and was very similar to WLW’s, both in field intensity at the point of mode transition and the distance to mode transition.

Exhibit M – Performance Maps & Charts

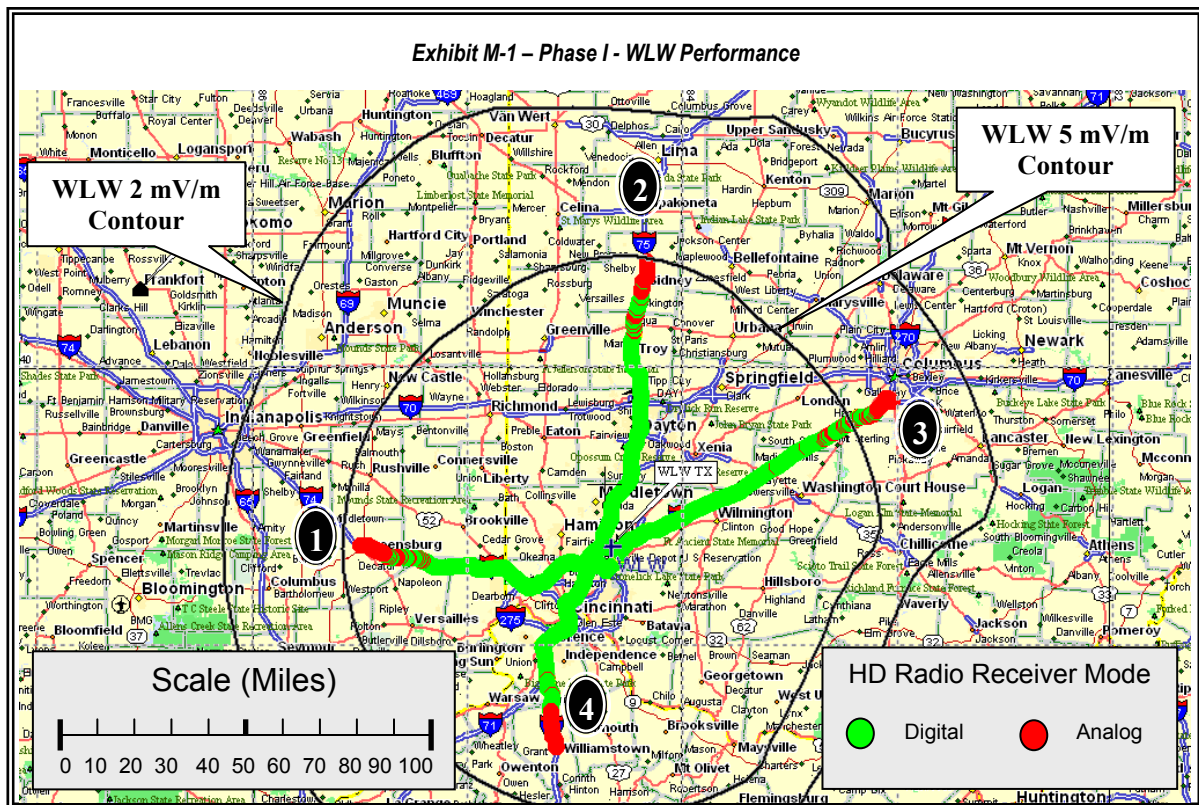


Exhibit M-2 – Phase II - WOR Performance – WLW HD Radio Carriers On

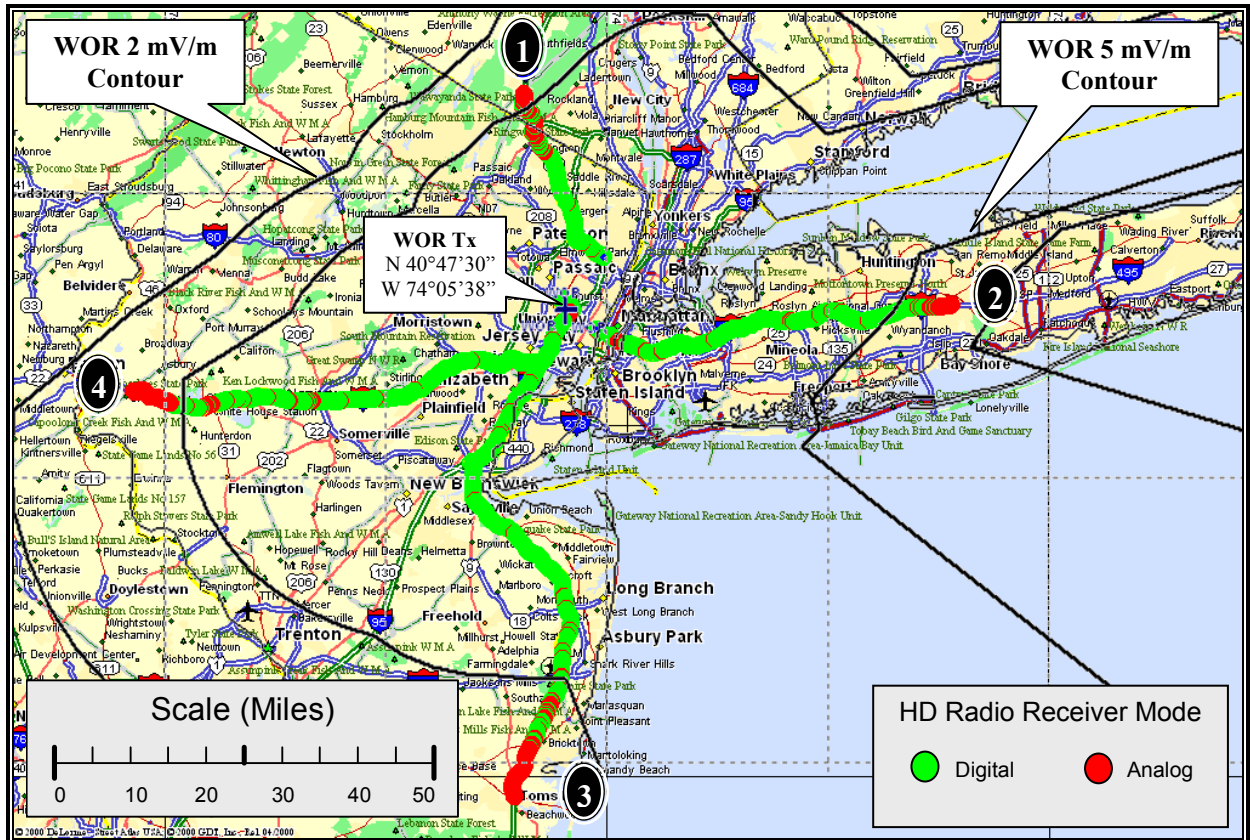


Exhibit M-3 – Phase II - WOR Performance – WLW HD Radio Carriers Off

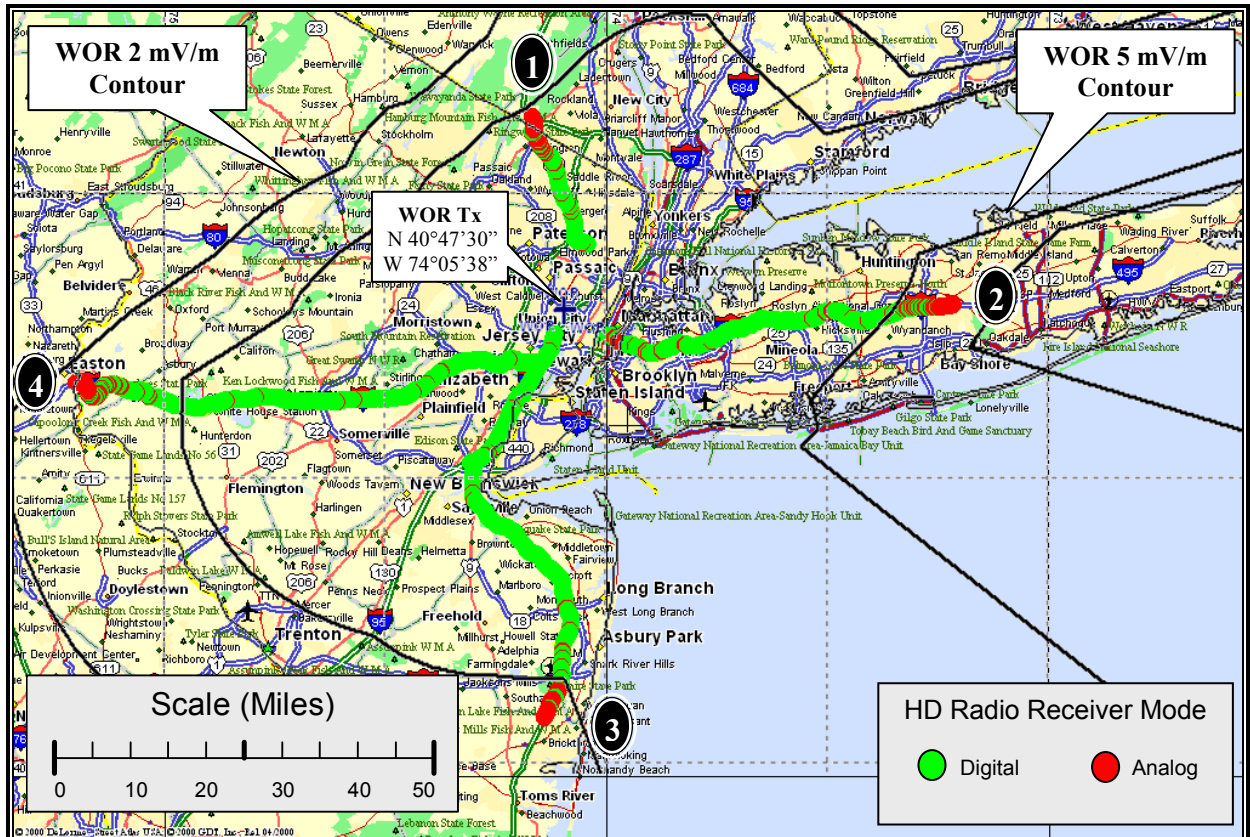


Exhibit M-4 – Phase I - WLW Night Performance (Route #2)

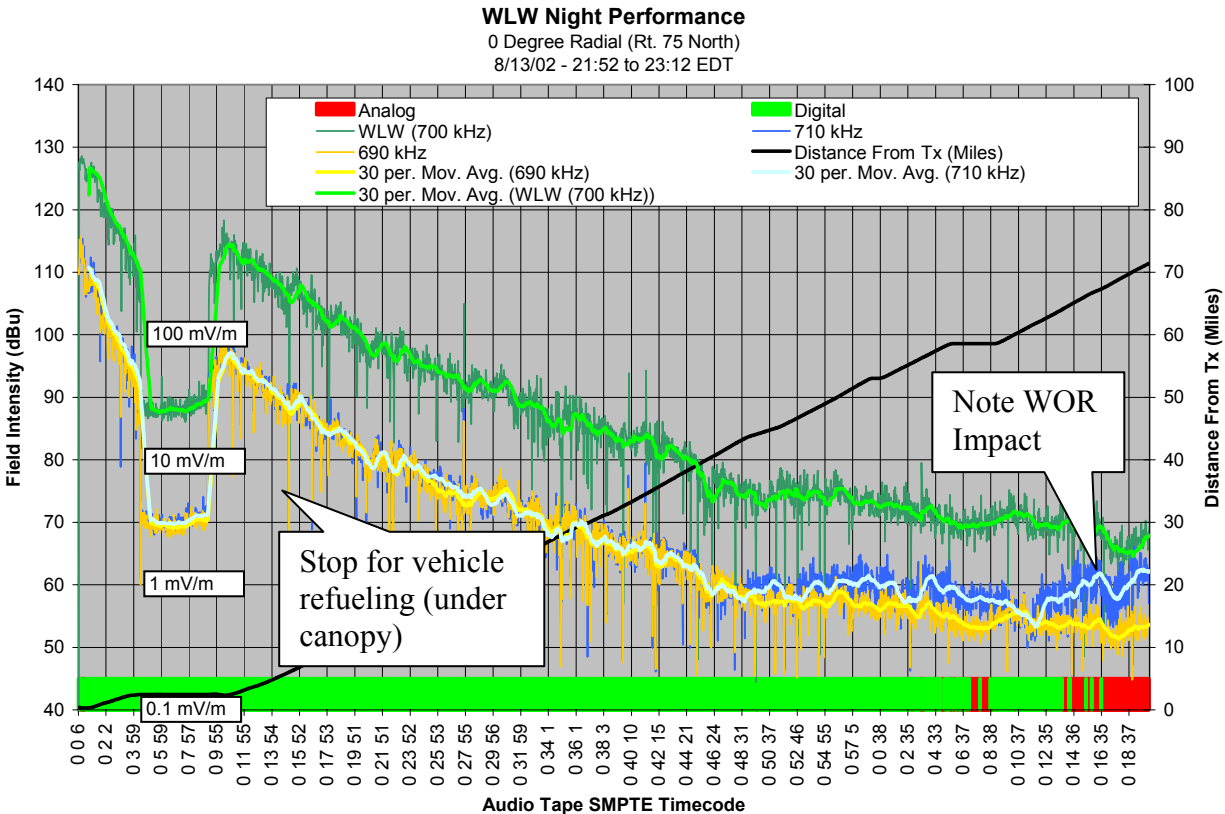


Exhibit M-5 Phase I - WLW Night Performance (Route 3)

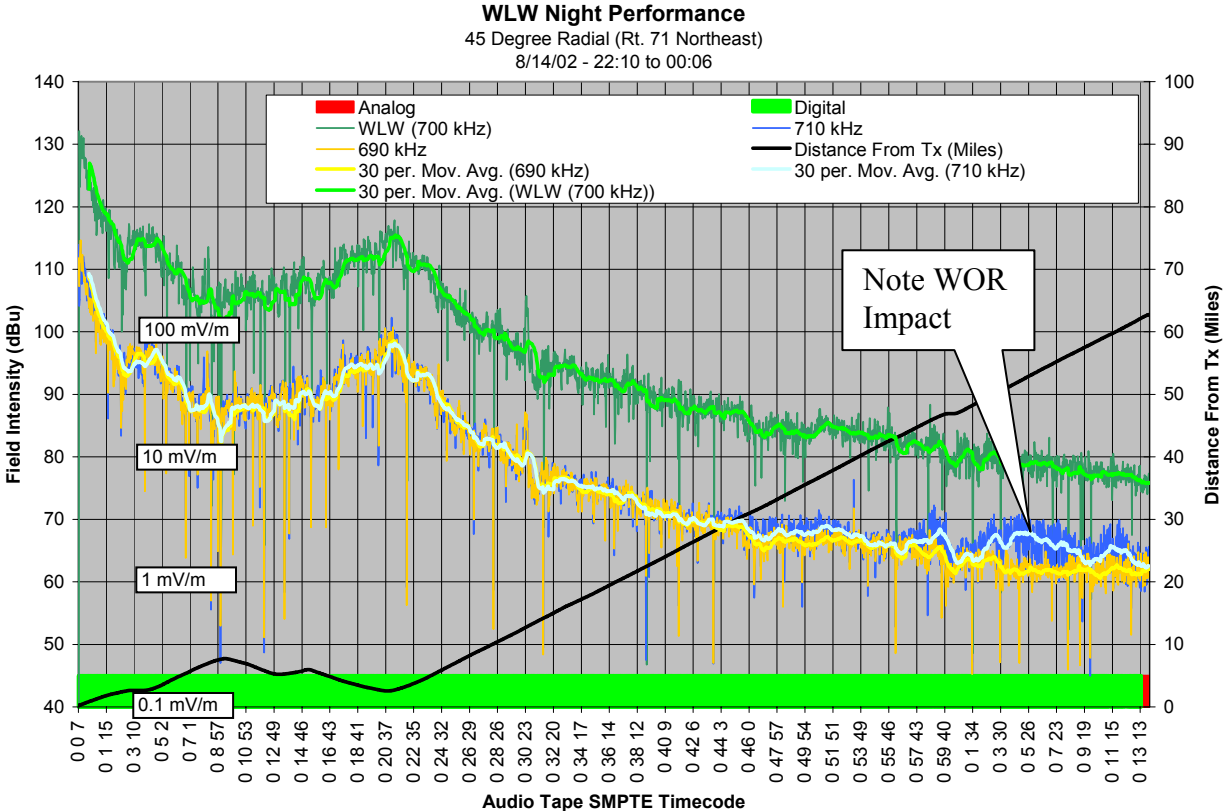


Exhibit M-6 – Phase I - WLW Night Performance (Route #4)

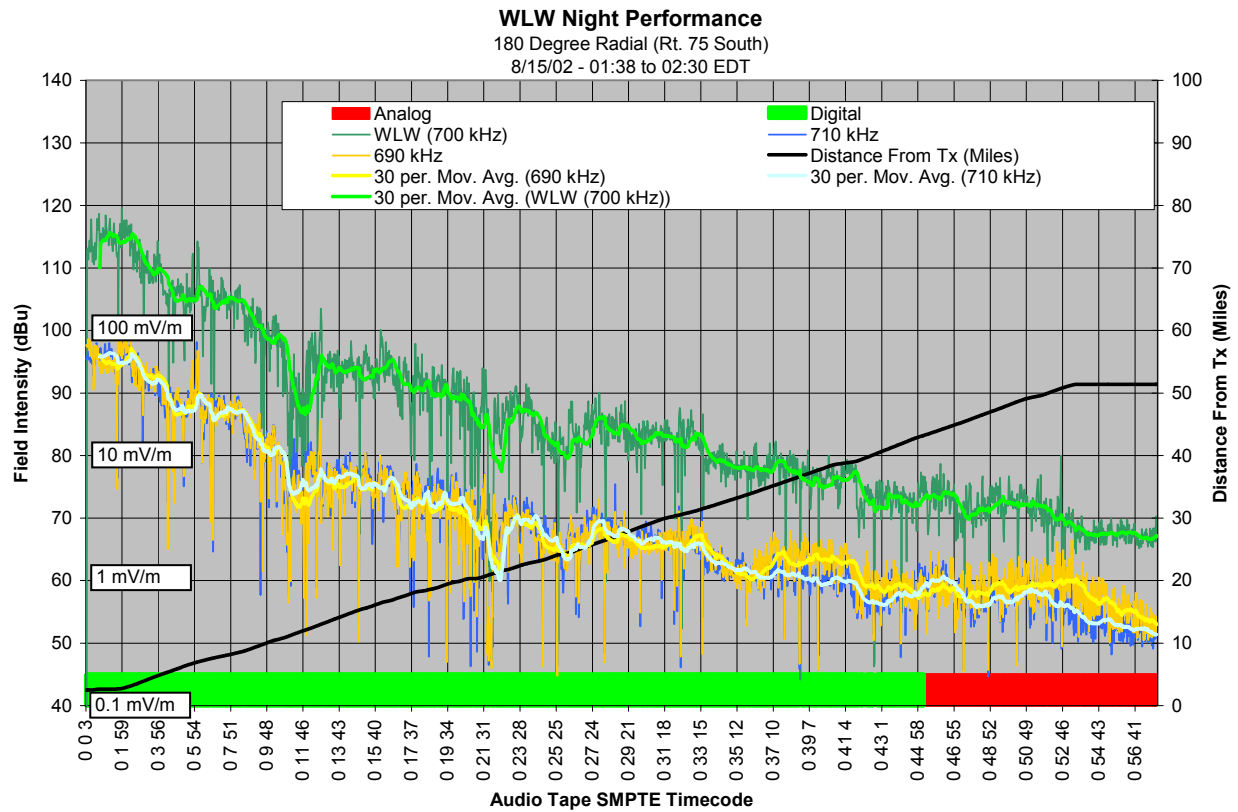


Exhibit M-7 – Phase I - WLW Night Performance (Route #1)

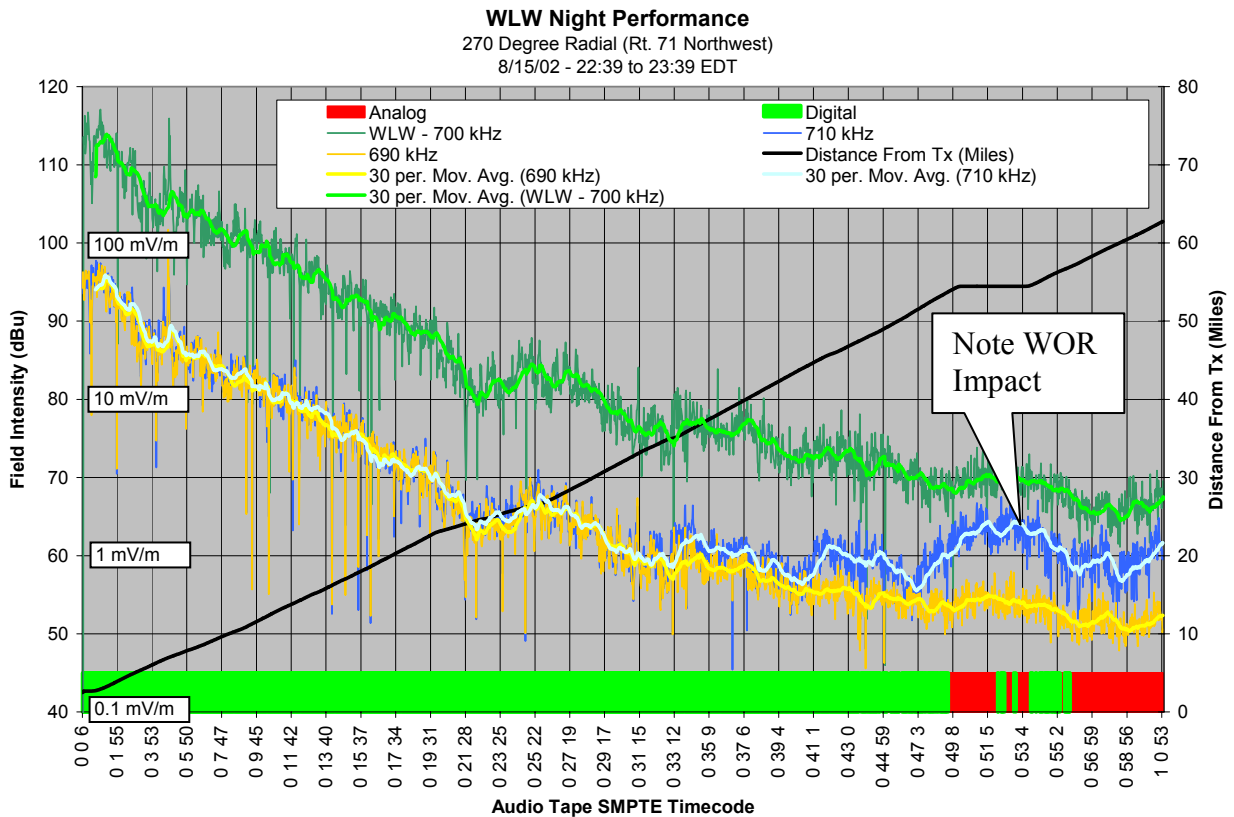


Exhibit M-8 – Phase II - WOR Night Performance With WLW HD Radio On (Route #1)

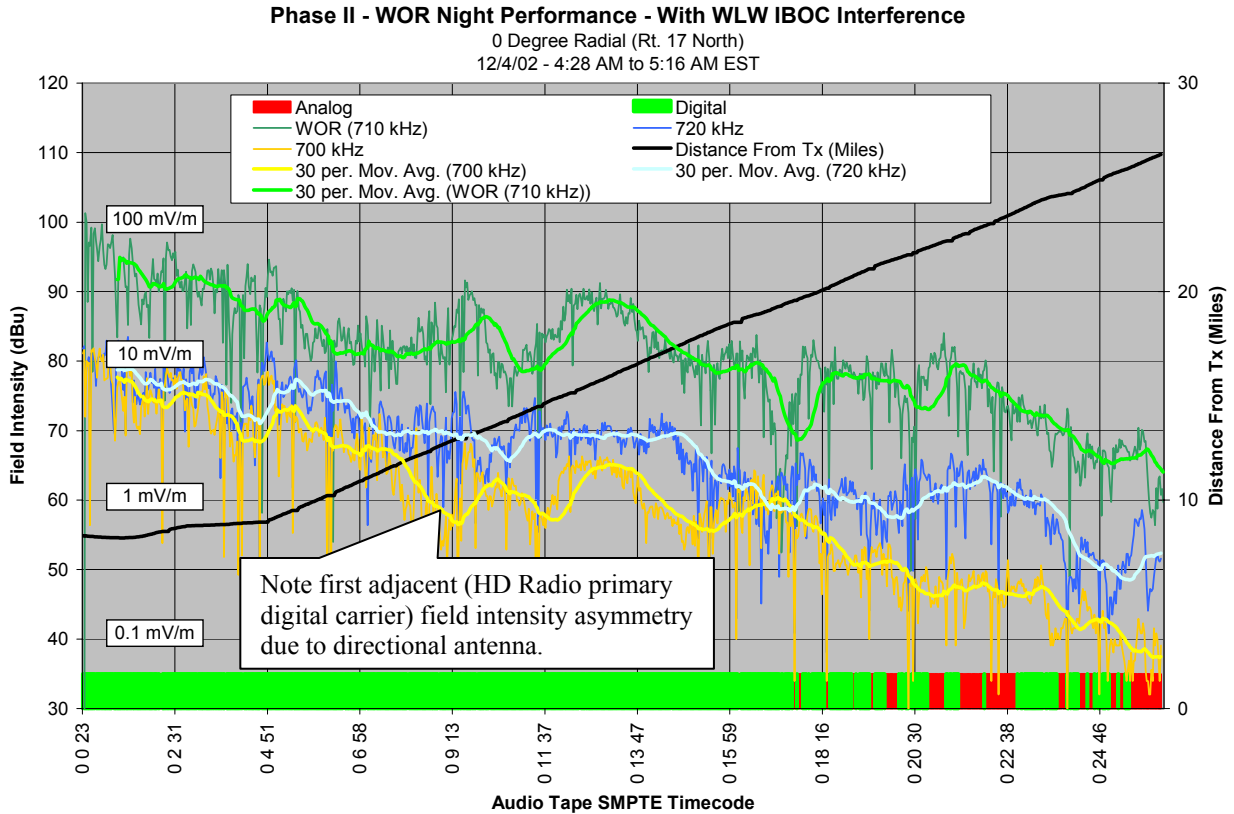


Exhibit M-9 – Phase II - WOR Night Performance With WLW HD Radio Off (Route #1)

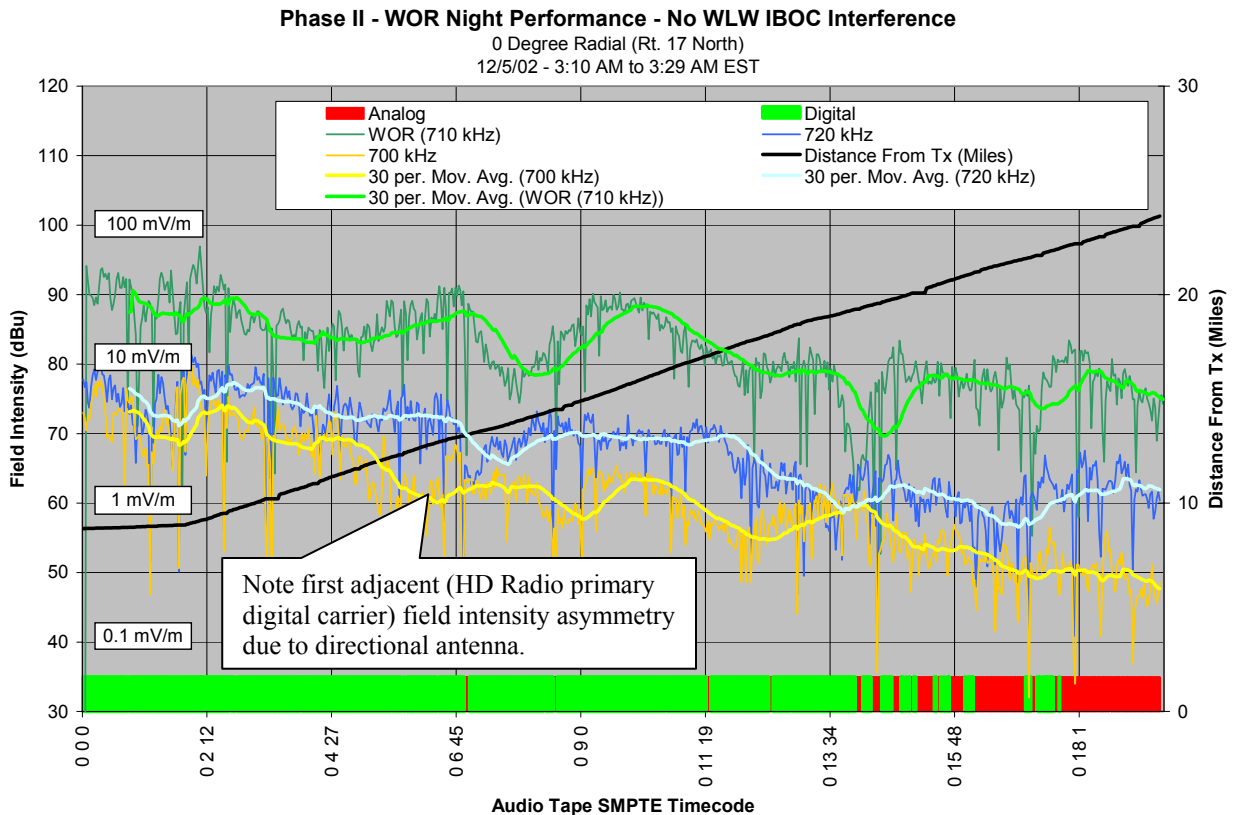


Exhibit M-10 – Phase II - WOR Night Performance With WLW HD Radio On (Route #2)

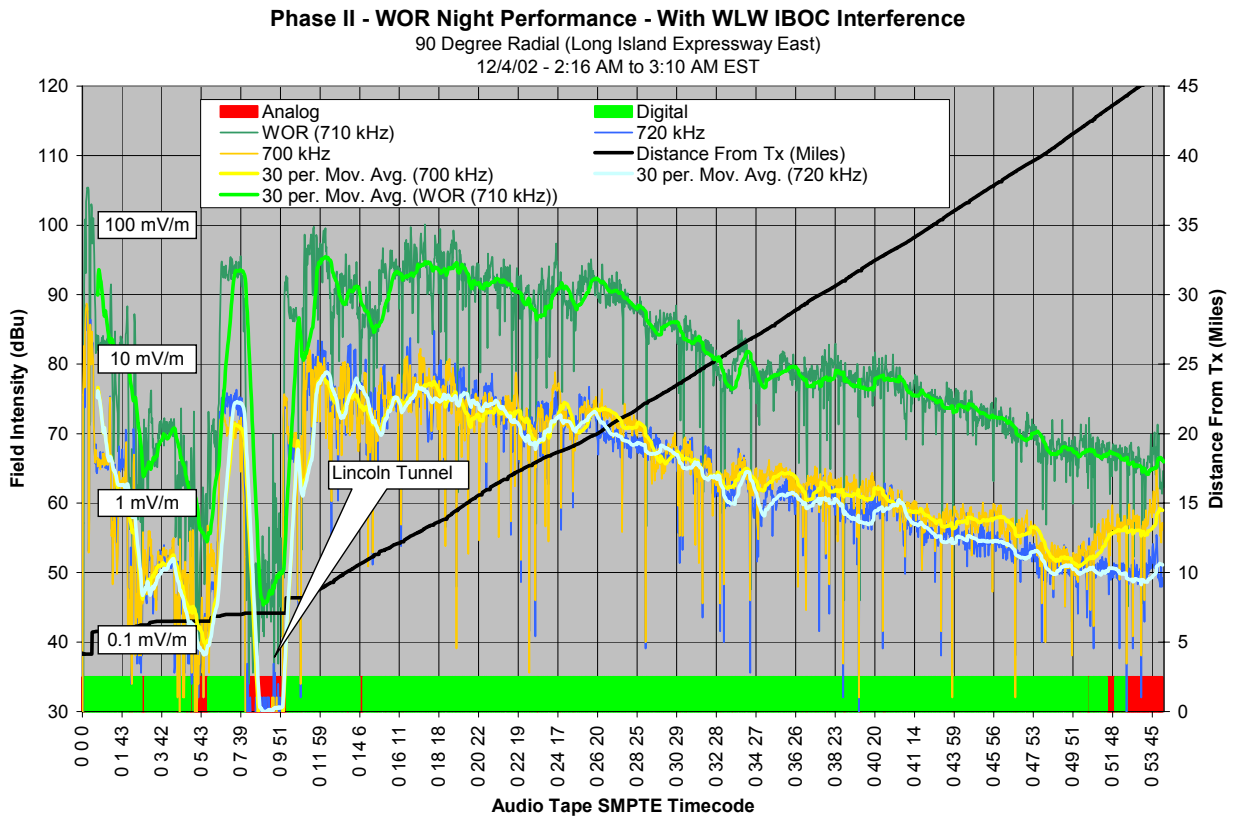


Exhibit M-11 – Phase II - WOR Night Performance With WLW HD Radio Off (Route #2)

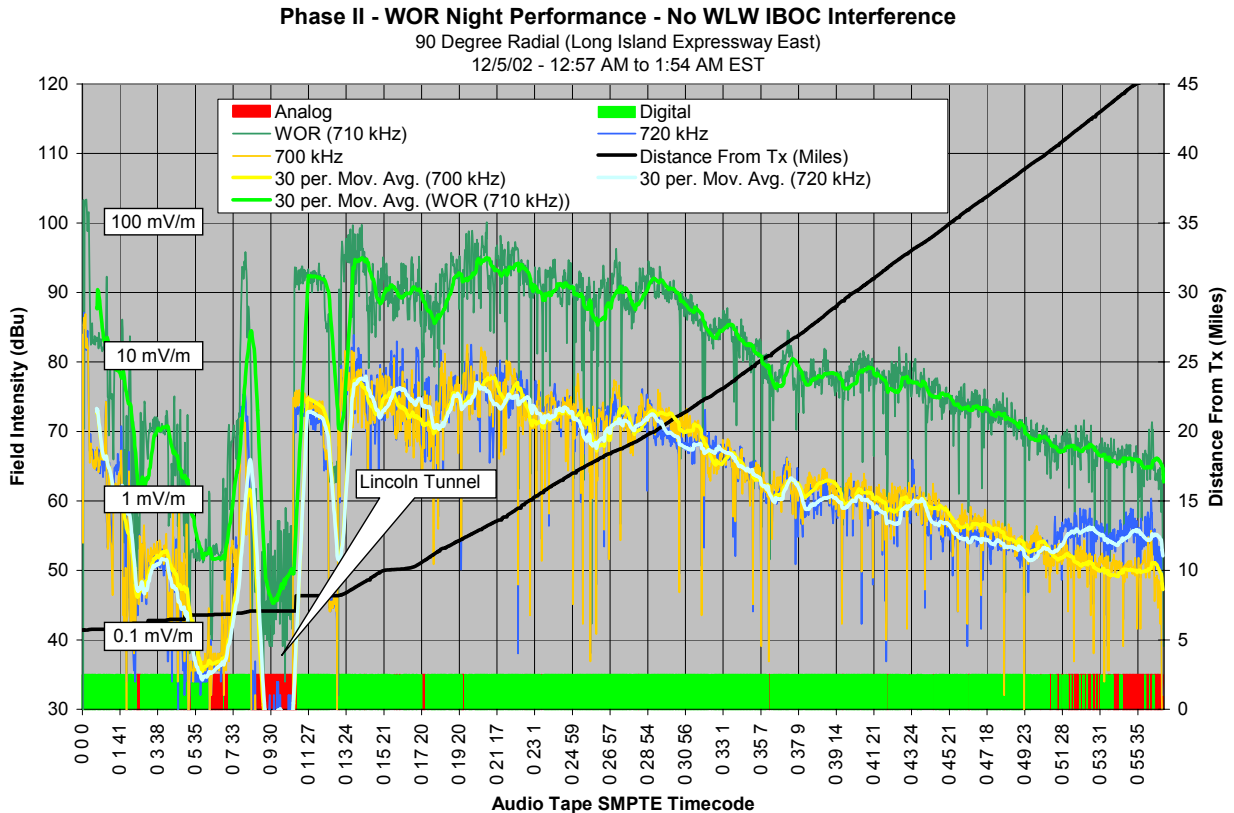


Exhibit M-12 – Phase II - WOR Night Performance With WLW HD Radio On (Route #3)

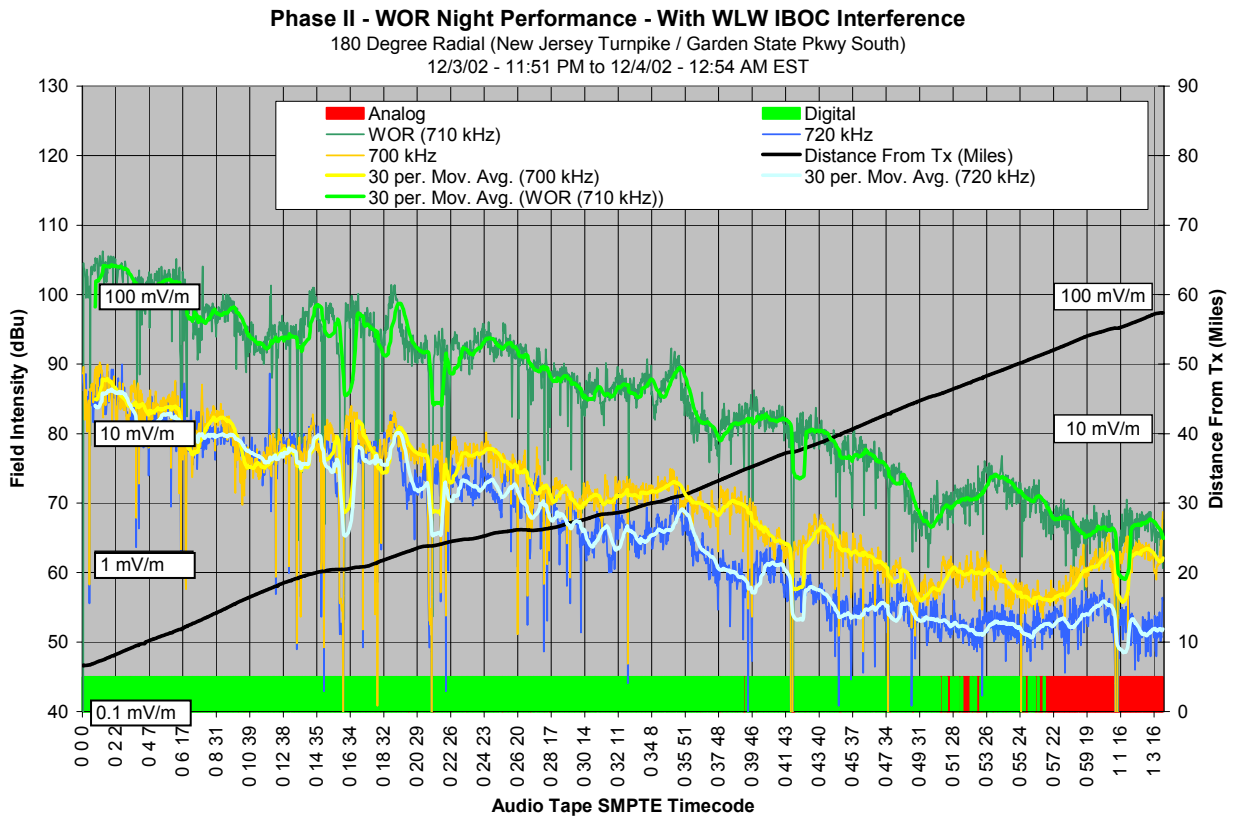


Exhibit M-13 – Phase II - WOR Night Performance With WLW HD Radio Off (Route #3)

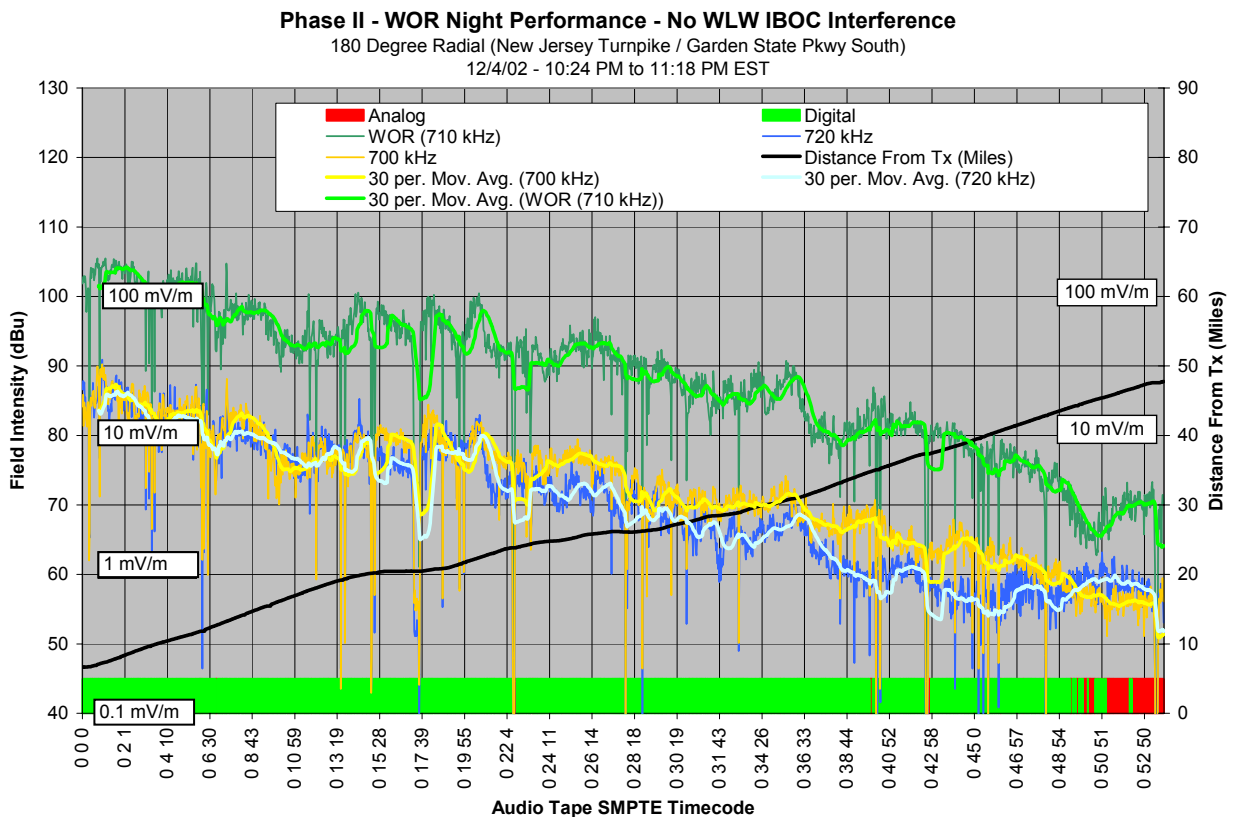


Exhibit M-14 – Phase II - WOR Night Performance With WLW HD Radio On (Route #4)

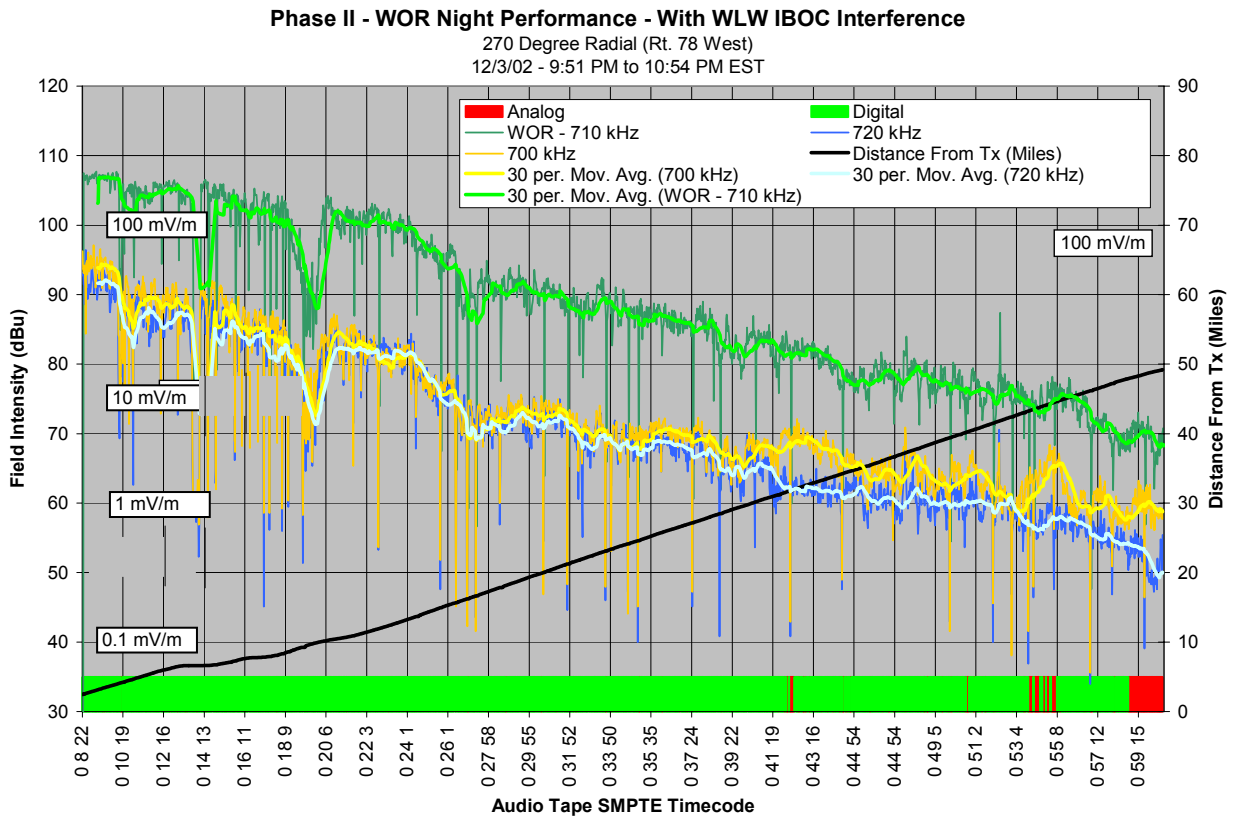


Exhibit M-15 – Phase II - WOR Night Performance With WLW HD Radio Off (Route #4)

